Iowa Department of Natural Resources
Environmental Protection Commission

ITEM **9** **DECISION**

TOPIC **Contract - Iowa State University - Evaluation of On-Road and Laboratory Engine Dynamometer Emission Tests to Compare the Emission Reduction Potential of Different Biodiesel Blends**

The Department requests Commission approval of a contract in the amount of $112,598 with Iowa State University (ISU) for the period of July 10, 2007 through June 30, 2008. The contract establishes cost reimbursable payments, funded through an external grant from the Central States Air Resource Agencies (CenSARA).

ISU's Center for Transportation Research and Education (CTRE) shall be responsible for the duties, technical reporting, and activities required to complete the project. The purpose of this contract is to allow the CTRE team to evaluate and compare the emission reduction potential of different biodiesel blends under different operating conditions. The team will conduct engine dynamometer tests as well as on-road tests which utilize a portable emissions monitoring system (PEMS). The research team will lease a portable on-road emissions measurement system from Clean Air Technologies. The Department of Mechanical Engineering at ISU currently has an engine lab setup with two diesel engines which are mounted to a dynamometer.

Biodiesel use in the state of Iowa will continue to become more prevalent. The tests and quantifications of the effects of different blends on engine and vehicle performance, and the subsequent air emissions that is obtained through this project can be used by the DNR to gain a better understanding of the environmental impacts of biodiesel for further guidance and planning should the state of Iowa reach non-attainment for Ozone.

Jim McGraw, Program Development Supervisor
Air Quality Bureau
Environmental Services Division

Memo Date: June 11, 2007

IOWA DEPARTMENT OF NATURAL RESOURCES

AGREEMENT NUMBER 08-7210-01
With

IOWA STATE UNIVERSITY

Agreement Title: Evaluation of On-Road and Laboratory Engine Dynamometer Emission Tests to Compare the Emission Reduction Potential of Different Biodiesel Blends

Agreement Amount:	**not to exceed** $112,598.00
Time of Performance:	July 10, 2007 to June 30, 2008
DNR Project Manager	Jim McGraw DNR-Air Quality Bureau 7900 Hickman Rd, Suite 1 Urbandale, IA 50322 515-242-5167
Submit Original Invoice and two copies to:	Shirley Christoffersen, Budget Analyst Department of Natural Resources Wallace State Office Building Des Moines, IA 50319-0034 ATTN: Budget and Finance Bureau
Issue Payment to:	Iowa State University Sponsored Programs Accounting 3609 Administrative Services Building Ames, Iowa 50011-3609 Federal Employer ID# 42-600-4224

Iowa State University agrees to deliver all supplies and perform all services set forth in the attached Special Conditions for the consideration stated herein. This contract contains 11 articles.

IN WITNESS THEREOF, the parties hereto have executed this agreement on the day and year last specified below.

IOWA STATE UNIVERSITY

By: _____
Anne Kinzel, Senior Awards Administrator
Date: _____

DEPARTMENT OF NATURAL RESOURCES

By: _____
Liz Christiansen; Deputy Director
Date: _____

This agreement was approved, as required by Subsection 455B.105(6) of the Code of Iowa, by the Environmental Protection Commission on [DATE]

SPECIAL CONDITIONS

ARTICLE I IDENTIFICATION OF PARTIES

This contract is entered into by and between the Iowa Department of Natural Resources (hereinafter referred to as DNR) and the Iowa State University (hereinafter referred to as ISU). ISU's Center for Transportation Research and Education (CTRE) shall be responsible for the duties, technical reporting, and activities required to complete the project.

ARTICLE II STATEMENT OF PURPOSE

This contract is entered into for the purpose of fulfilling the solicitation proposal submitted to the Central State Air Resources Agencies (CenSARA) for the evaluation of on-road and laboratory engine dynamometer emission tests to compare the emission reduction potential of different biodiesel blends.

Biodiesel use in the state of Iowa will continue to become more prevalent. The DNR can use the data obtained during the project to gain a better understanding of the environmental impacts of biodiesel for further guidance and planning should the state of Iowa reach non-attainment for Ozone.

ARTICLE III TIME OF PERFORMANCE

This contract shall be effective on July 10, 2007. Performance by ISU shall commence after this agreement has been signed, but not prior to July 10, 2007. The performance required herein shall be completed by June 30, 2008, unless changed by mutual written agreement.

ARTICLE IV DESIGNATION OF OFFICIALS

4.1 DNR. The Deputy Director of the Department shall be the official authorized to execute any changes in terms, conditions, or amounts specified in this agreement. The DNR Project Manager is designated by the Deputy Director to negotiate, on behalf of the Department, and subject to the approval of the Deputy Director, any changes to this agreement.

4.2 ISU. The Senior Awards Administrator at the Iowa State University shall be the official authorized to execute any changes in terms, conditions, or amounts specified in this agreement. The following individuals are designated as Key Personnel subject to section 11.3 of the General Conditions: **Shauna Hallmark** (Associate Professor at Department of Civil, Construction, and Environmental Engineering and Research Engineer at CTRE), **Dennis Kroeger** (Transportation Research Specialist at CTRE) and **Dr. Song-Charng Kong** (Assistant Professor at Department of Mechanical Engineering).

4.3 The above officials shall represent their respective agencies in all matters necessary to the successful completion of this contract. In the event that ISU proposes a change in the individuals designated as Key Personnel, the DNR shall be notified in writing not later than ten (10) working days prior to the proposed effective date of the change.

ARTICLE V SCOPE OF WORK

5.1 The Scope of Work consists of Task 1, 4, and 6, as outlined in Exhibit B. Tasks 2, 3, and 5 of Exhibit B are not included as part of the Scope of Work*.

Deliverable(s): ISU shall provide a monthly progress report to the DNR Project Manager in accordance with Article VI, 6.1.

5.2 Incorporation of Documents. The following documents, and any amendments thereto existing on the date this contract is signed by DNR, are incorporated into this contract by this reference: (1) the CenSARA subaward (#07-0502-BSC-001) document ,attached as Exhibit A; (2) the document entitled "Evaluation of On-Road and Laboratory Engine Dynamometer Emission Tests to Compare the Emission Reduction Potential of Different Biodiesel Blends, dated January 30, 2007, as amended by the document of the same name dated March 29, 2007, attached as Exhibit B; and (3) the document entitled "CenSARA; Blueskyways Collaborative – Request for Proposals", released November 22, 2006, attached as Exhibit C.

5.3 Preference. In the case of any inconsistency or conflict between the provisions of this document (including all related schedules and Statements of Work), the RFP or the Contractor's Proposal, the inconsistency or conflict shall be resolved as follows: (1) by giving preference to the provisions of this document (including any Statements of Work); (2) the CenSARA subaward (#07-0502-BSC-001) document ,attached as Exhibit A; (3) the document entitled "Evaluation of On-Road and Laboratory Engine Dynamometer Emission Tests to Compare the Emission Reduction Potential of Different Biodiesel Blends", dated January 30, 2007, as amended by the document of the same name dated March 29, 2007, attached as Exhibit B; and (4) the document entitled "CenSARA; Blueskyways Collaborative – Request for Proposals", released November 22, 2006, attached as Exhibit C.

[*]These tasks (2, 3, and 5) were not provided funding under the solicitation offer accepted by CenSARA, therefore they are not included in the Scope of Work.

ARTICLE VI GENERAL REPORTS

6.1 Monthly Progress Reports. ISU shall submit to the DNR Project Manager, according to the schedule set forth in Article VI, Section 6.2, written progress reports on the scope of work items identified in Article V, Section 5.1. The report shall include, but not be limited to, the following:

a) activities completed to meet the respective work items identified in Article V,
b) a description of any obstacles that would delay completion of each respective work item, and
c) any requested adjustments in completion dates of each work item.

If, in the determination of the DNR Project Manager, additional item(s) need to be included in the Monthly Progress Reports, the DNR Project Manager will provide written notice of the request for additional items to the Research Engineer at CTRE (Shauna Hallmark), at least thirty (30) days prior to a report being due.

6.2 Monthly Report Schedule. Monthly progress reports are due on or before the listed due dates.

Reporting Period	Reports Due
July 10-31, 2007	August 5, 2007
August 1-31, 2007	September 5, 2007
September 1-30, 2007	October 5, 2007
October 1-31, 2007	November 5, 2007
November 1-30, 2007	December 5, 2007
December 1-31, 2007	January 5, 2008
January 1-31, 2008	February 5, 2008
February 1-28, 2008	March 5, 2008
March 1-31, 2008	April 5, 2008
April 1-30, 2008	May 5, 2008

6.3 Final Report. The final report shall consist of the reporting requirements outlined in Task 6 of Exhibit B. ISU shall submit the final report to the DNR Project Manager no later than May 30, 2008.

ARTICLE VII DNR RESPONSIBILITIES

The DNR will be responsible for the execution of grant management responsibilities and for providing technical assistance. These services will include reviewing and commenting on all information obtained from the research/project team, and providing financial and technical oversight for the project. Financial and technical oversight includes, but is not limited to, reviewing and processing of all payment requests, reviewing and commenting on monthly activity reports, facilitating communications between ISU and other project partners, and providing guidance to ISU regarding the development of documents, reports, and materials to allow for the widest dissemination and use of the project results with other agencies.

ARTICLE VIII CONTRACTUAL MONITORING

8.1 If there is an occasion of unsatisfactory performance by ISU, the DNR will notify ISU in writing. ISU shall then have thirty (30) calendar days from receipt of the notification to submit a written response in rebuttal to the allegations of unsatisfactory performance and/or a report of corrective actions taken.

8.2 All information generated by the terms and conditions of this contract, including all relevant exhibits, shall remain in the public domain. ISU shall pay all license fees and royalties and assume all costs incidental to the use or possession of any Intellectual Property in accordance to all terms identified in Exhibit A.

8.3 ISU shall submit to the DNR Project Manager, via hard copy or in an electronic version of *Microsoft Word*, an original unbound copy of each non-financial document or report prepared under this contract by the deadlines specified in Article VI.

8.4 The DNR and CenSARA Project Managers, as identified in Exhibit A, shall have the right to review and observe, at any time, completed work or work in progress. The "right to review" includes, but is not limited to, the ability to schedule an audit to examine paperwork, materials, etc. prepared pursuant to this contract.

8.5 ISU shall not release any information relating to the work of this contract to the news media without specific written authorization from the DNR.

8.6 ISU shall maintain books, records, documents, and other evidence reasonably pertinent to the performance of this contract during the performance of this contract and for three (3) years thereafter.

8.7 If agreed upon by both parties, this contract may be amended under the guidelines of Exhibit A.

ARTICLE IX CONDITIONS OF PAYMENT

9.1 ISU shall receive payment only for actual costs incurred and invoiced in accordance with the budget categories found in Article XI. This contract is funded solely by CenSARA Subaward No. 07-0502-BSC-001.

9.2 DNR may terminate this contract for cause within the meaning of Section 6.0 of the General Conditions.

9.3 DNR shall make timely payments to ISU after receipt of an accurate invoice and in accordance with the schedule of budget categories payments found in Article XI. The DNR may refuse to make payment of all or part of the amount invoiced for items of work or service which in the determination of DNR, do not meet the specifications of this contract. If the item of work or service is resubmitted by a date agreed to by DNR and ISU and is determined by the Deputy Director to be satisfactorily completed according to the specifications of this contract, then payment shall be processed.

ARTICLE X AGREEMENT PAYMENT SCHEDULE

10.1 ISU shall submit monthly invoices regardless of the amounts of supplies purchased or services performed. For each payment due under this agreement, ISU shall submit an original and two (2) copies of its invoice to the DNR-Budget and Finance Bureau at the same time monthly reports are due (see Article VI, 6.2).

10.2 The contract total payment shall not exceed $112,598.00 from July 10, 2007 through June 30, 2008. All contracted duties and activities shall be performed by ISU regardless of further reimbursement being available from the DNR.

10.3 The final invoice shall be due no later than June 1, 2008. Payment of the final invoice shall be withheld until receipt and acceptance by DNR of ISU's final performance report, as set forth in Article VI, Section 6.2.

ARTICLE XI BUDGET

Category	Task 1	Task 4	Task 6
Salaries and Fringe	$2,579	$11,385	$1,252
Travel		$384	
Student Work	$10,892	$7,054	
Equipment Rental (fuel tank/engine dynamometer)	$4,000	$3,750	
Subcontract for PEMS		$45,000	
Equipment installation/fuel draining		$2,170	
Telecommunications		$20	
Printing/Copying		$100	
Communications Services			$779
Direct Costs	$17,471	$69,863	$2,031
Indirect Costs	$4,542	$18,163	$528
TOTALS by Tasks	**$22,013**	**$88,026**	**$2,559**

Exhibit B
Contract 08-7210-01

Title: Evaluation of On-Road and Laboratory Engine Dynamometer Emission Tests to Compare the Emission Reduction Potential of Different Biodiesel Blends

PROJECT LEAD: Jim McGraw, Environmental Program Supervisor, Program Development Section, Air Quality Bureau, Iowa DNR. Phone: (515) 242-5167. Email: Jim.McGraw@dnr.state.ia.us.

Proposing Organization: Iowa Department of Natural Resources (DNR) with Center for Transportation Research and Education (CTRE) at Iowa State University (ISU) as subcontractors.

CTRE Team: Shauna Hallmark (PI), phone: (515) 294-5249, email: shallmar@iastate.edu; Song-Charng (Co-PI), Mechanical Engineering, Phone (515) 294-3244, email: kong@iastate.edu; Dennis Kroeger (co-PI). Center for Transportation Research and Education, Iowa State University. 2711 S. Loop Drive, Suite 4700, Ames, IA 50010-8664. Fax: (515) 249-0467.

DATE: January 30, 2007

SUBMITTED TO: Central States Air Resource Agencies Association. Mr. Jeffery Cole, email: jcole@censara.org

1. **BACKGROUND**
2. **SCOPE OF PROJECT**
3. **PROJECT PARTNERS AND ROLES**
4. **PROJECT TEAM**
5. **EQUIPMENT**
6. **GENERAL METHODOLOGY**

Each objective corresponds to a specific task or subtasks. Each is described in the following sections. Since the methodology and study are specific to each task, that information is provided for each task.

Fuel will be purchased from Western Central COOP, a supplier of biodiesel or one of their clients. The facility is capable of blending different fractions of biodiesel. A portable fuel tank will be rented to use during the project since Western Central Coop is approximately 50 miles from Ames, Iowa and fueling vehicles at the site is not practical. Fuels will be purchased from Western Central COOP for both the on-board and laboratory engine dynamometer tests. The same blends will be also be used for the on-board and laboratory test so that results for each blend are comparable.

Task 1: Evaluate and compare emissions for regular diesel and different biodiesel blends using laboratory engine dynamometer tests

Background

In-laboratory engine dynamometer tests will be performed to compare the emissions from regular diesel and different biodiesel blends for Task 1. The engine test facilities are described in Section 5.2. As noted the regular diesel fuel used in this study is ultra low sulfur diesel (ULSD) fuel. Previously published test data on biodiesel combustion were mainly based on diesel fuel with higher sulfur contents. Since the mandate of using ULSD has come into effect for on-highway vehicles, it is important to characterize the engine performance of using biodiesel blended with ULSD. In addition, new diesel emissions standards have resulted in the development of low-emission engines that are known to operate at different combustion regimes from the older models. It is also important to re-do the tests on new engines such as the new engine that is available in our laboratory that uses a start-of-the-art injection system.

Study Area: All of Task 1 will be conducted in the engine dynamometer lab on Iowa State Campus in Ames, Iowa.

Methodology: Extensive engine tests will be performed on a commercial turbocharged multi-cylinder engine manufactured by John Deere. Emissions will be evaluated using regular USLD and 2%, 5%, 10%, and 20% biodiesel blends. The test will measure engine power and exhaust emissions. Fuel economy and particulate and gaseous emissions, including NO_x, HC and CO, will be recorded.

The first replication will evaluate USLD. For each fuel type, three different load conditions that are representative of regular engine operation will be tested. This includes peak torque (1400 rpm, 220 ft-lb), rated power (2100 rpm, 187 ft-lb) and light load (1200 rpm, 30 ft-lb). Steady-state tests will be performed with 20 minutes of each load conditions.

A data acquisition system is already in place in the engine laboratory. The data system is capable of acquiring fueling rate, engine power and all the emissions data automatically. The data are averaged over the duration of each individual test. The data will be analyzed to assess each of the emission with respect to the fuel type. Data from Replication 1 will be evaluated to check data quality. If problems are noted in the data or equipment malfunctions occur, Replication 1 will be repeated before fuels are switched for Replication 2.

Replication 2 will use USLD blended with 2% biodiesel. The test protocol for Replication 1 will be followed. USLD will be blended with 5% biodiesel for Replication 3, 10% for Replication 4, and 20% for Replication 5 and the test protocol repeated as for Replication 1. In order to eliminate the effects of residual biodiesel in the fuel system, the engine will be run using regular diesel fuel for 15 minutes between replications.

Data from each replication will be evaluated in terms of emissions by load. Emissions are measured in terms of engine loads in units of g/kW-hr. As a result, the emission measurement is mass of emissions per unit fuel energy burned. More engine loading translates to more fuel energy and higher emission. As a result relationships between loading and emissions will be derived for each fuel blend.

Results: This task will result in a set of relationships between heavy-duty diesel engine load and emissions for different biodiesel blends. This information will be presented in a format so that the impact of using different biodiesel blends on heavy-duty vehicle emissions can be estimated.

For instance, a trucking or transit agency can use to results to evaluate the emissions reduction likely to result from dedicated use of 2%, 5%, 10%, or 20% biodiesel and determine the feasibility of using dedicated fleet refueling stations with biodiesel blends. Agencies concerned about PM, NOx, HC, ozone, or CO can also use this information to forecast emissions reductions from control strategies that encourage use of biodiesel. These results are applicable across all agencies within the CenSARA region.

Study length: Task 1 will take approximately 6 months.

Type of Emissions Measured and Estimation of Time Emissions are present: Since this is a laboratory test emissions are present at all times during the test. The emissions under study include particulate matter, NO_x, CO and HC.
Cost: This approximate cost for this task is $13,748.

Task 2: Investigate effects of 2% biodiesel in ultra low sulfur diesel (ULSD) on engine wear

Task 3: Investigate effects of "on-spec" and "off-spec" biodiesel on engine fuel efficiency, and particulate and NOx emissions

Task 4: Evaluate and compare on-road emissions for regular diesel and different biodiesel blends

Background: A more complex relationship exists between engine operation and the rate of emission production than is typically evaluated using engine or chassis dynamometer tests. On-road emissions can vary dramatically since emissions are correlated to engine mode and activity such as idling, acceleration, deceleration, and operation against a grade produce higher emissions than more stable engine operating mode (Pierson et al., 1996; Cicero-Fernandez et al., 1997; Enns et al., 1994; CARB 1997; Le Blanc et al., 1995). Since these modes are not well captured in a laboratory environment, understanding on-road relationships is critical in evaluating the emissions reductions that may be possible with biodiesels.

This task will evaluate emissions from regular diesel and different blends of biodiesel from on-road engine operation using transit buses along a set existing transit route from the City of Ames, Iowa's transit system, CyRide. Evaluation of transit buses was selected for this study rather than heavy-duty trucks since transit buses have a regular route so emissions for each of the biodiesel blends can be compared across the same operating conditions. Additionally, truck owners are reluctant to allow evaluation of higher blends of biodiesel due concerns of engine maintenance. CyRide is already using 10% biodiesel and is considering use of 20%. As a result, different biodiesel blends can be evaluated without entailing liability from vehicle owners.

Additionally, it is not currently possible for long-haul trucks to use a higher biodiesel blends due to the limitation in availability at fueling stations. As a result, currently it is only convenient for transit buses to use higher biodiesel blends since those fleets have their own fueling stations. There are numerous city transit agencies that are currently using biodiesel blends in Iowa including Ames (CyRide), Iowa City, Cedar Rapids, Waterloo and Sioux City. School districts are also capable of converting their fleet to biodiesel as they also often have their own fueling stations. As a result transit and school buses are likely to be the first significant users of higher blends of biodiesels.

Transit buses also have engines that are similar to those for heavy-duty trucks and EPA emissions standards are almost identical for heavy-duty truck and urban bus engines. The engines are all heavy-duty diesels and emissions for all heavy-duty diesel vehicles are measured in terms of engine loads in units of g/kW-hr. As a result, the emission measurement is mass of emissions per unit fuel energy burned. More engine loading due to weight, acceleration, or other factors, translates to more fuel energy and higher emission. As a result some relations can be derived between the transit studies and heavy-duty trucks.

Study Area: This task will be completed in Ames, Iowa along one of CyRide's fixed operating routes. CyRide is the city bus system for Ames, Iowa and is collaboration between the city and Iowa State University (ISU). CyRide has 10 fixed routes which serve a large portion of the City of Ames and Iowa State (CyRide, 2007). The fixed routes operate every day of the year except Thanksgiving, Christmas and New Year's Day. CyRide carries an average of 4,173,197 passengers per year.

Methodology: We plan to instrument 2 CyRide transit buses with a portable emissions monitoring system described in Section 5.1 to evaluate emissions during on-road operation using the regular and different biodiesel blends.

CYRIDE has 66 buses. The majority were purchased between 1990 and 2006 and fall under either Tier (1998 to 2004) or Tier (2004 to 2007) emission standards. Our intent is to evaluate both a Tier 1 and Tier 2 bus.

Both buses will be evaluated on a single existing CyRide route. The test route will be selected to represent a wide range of activity and ideally will include:

- A section with significant stops and starts at lower speeds (15 to 25 mph) (similar to a campus route)
- A section with mid-range speeds (35 to 45 mph) and stops and starts (arterial with regularly spaced signals)
- A mile or more section at mid to high speeds of constant flow (arterial with widely spaced arterial)
- A mile or more section at high speed (55 to 65 mph) (freeway section)

At least one existing route meets the first three criteria. None of the routes traverses a freeway, expressway, or long arterial section with a speed limit greater than 45 mph. A separate test will be conducted where both buses traverse a test run along an expressway or freeway in order to include a section at high speeds. US 30, a 4-lane divided expressway is located just south of Ames and US 35, a 4-lane freeway is adjacent to the Ames on the east which will facilitate including a high speed test section. All other testing will be conducted during the regular scheduled bus route.

Each bus will be evaluated using regular diesel (ULSD) and each of the biodiesel blends during different replications. We plan to alternate the two buses on the same route and use the same driver if possible. CyRide currently uses B10 biodiesel. Buses will be tested through 5 replications using each of the five fuel blends (USLD, 2% biodiesel, 5% biodiesel, 10% biodiesel, and 20% biodiesel). Each replication will follow the protocol discussed in the following sections.

Replication 1
The first replication will evaluate the buses using the biodiesel blend currently used by CYRIDE (B10 biodiesel). During the first week of testing, Bus 1 will be instrumented with the PEMS.

Emissions will be tested over a 1 to 2 day period on the regular scheduled bus route. The PEMS will remain on the bus during the entire working day. CYRIDE operates approximately from 6:30 am to 11:30 pm. A graduate student will remain with the equipment during the daily tests in case of malfunction and to prevent theft. The study will be conducted Monday thru Friday and will avoid holidays, weekends, and special events so that traffic patterns are somewhat consistent between the replications.

Once the first replication for Bus 1 is completed, data will be downloaded and checked for errors, gaps, malfunctions, or other problems. If problems are noted in the data or any problems occur during the on-board test, the replication for the first bus will be repeated before the fuel is changed out of that bus in preparation for the next replication. Once data quality has been verified, Bus 2 will be instrumented with the PEMS and the same protocol will be followed.

Replication 2
While Bus 2 is tested for Replication 1, the fuel in Bus 1 will be changed out to a 5% biodiesel blend. We will discuss the best methodology to change fuels with CYRIDE and the fuel provider. Emptying the fuel tank and refilling with the next fuel would be the best option. If this is not feasible, we may need to refill the tank several times with 5% biofuel to ensure that a 5% blend is present in the fuel tank and engine during the actual testing.

Once Replication 1 is complete and data quality has been verified for Bus 2, Bus 1 will be instrumented and the test procedure outlined for Replication 1 will be followed. The fuel will be changed for Bus 2 (5% biodiesel) and it will be re-instrumented and tested

Replication 3
Replication 3 will follow the same procedure as Replication 1. The fuel blend for replication 3 will be 10% biodiesel.

Replication 4
Replication 4 will follow the same procedure as Replication 1. The fuel blend for Replication 4 will be 20% biodiesel.

Replication 5
Replication 5 will follow the same procedure as Replication 1. The fuel blend for the final replication will be regular ULSD.

The PEMS instrument will calibrated as often as necessary as per manufacturer recommendations.

A schedule is shown in Table 1. The schedule assumes that the buses will be evaluated over 1 to 2 days.

Table 1: Test Cycle for Task 1

Week	Test	Fuel
1	**Bus 1 Replication 1**	2% biodiesel
	Bus 2 Replication 1	
2	**Bus 1 Replication 2**	5% biodiesel
	Bus 2 Replication 2	
3	**Bus 1 Replication 3**	10% biodiesel
	Bus 2 Replication 3	
4	**Bus 1 Replication 4**	20% biodiesel
	Bus 2 Replication 4	
5	**Bus 1 Replication 5**	regular ULSD
	Bus 2 Replication 5	

The PEMS measures second-by-second mass emissions. Engine data, such as speed, acceleration, and throttle position, will also be recorded for the same period and linked to the second-by-second emissions data. The system GPS will be used to locate the bus along the roadway so that roadway characteristics can be included in the model as well.

Results: A statistical model will be developed that relates emissions to vehicle characteristics (speed, acceleration, engine load) and roadway characteristics. Relationships will be developed for the vehicle trip as well as different ranges of speed and acceleration which can approximate engine loading. Typical modal emissions models use power as the engine parameter. Models will be developed for each of the regulated transportation-related emissions NO_x, HC, CO, and PM. A model will also be developed for the greenhouse gas, CO_2. Results will be compared across fuels and engine operating mode. Additionally emission relationship derived for the on-road studies will be compared to the engine dynamometer tests.

Since transit buses have engines that are similar to those for heavy-duty trucks and EPA emissions standards are almost identical for heavy-duty truck and urban bus engines, results for the transit buses can be extrapolated for other heavy-duty vehicles. Emissions can be analyzed in terms of mass of emissions per unit fuel energy burned which is related to power. Information from the on-road emissions tests will be compared to results from the engine dynamometer tests and relationships will be derived that can be used to assess emission reductions from different categories of heavy trucks. In order to accomplish this, the load (e.g., vehicle weight, average number of passengers, vehicle operating mode) will be recorded as emissions data are recorded on the buses. Relationships to estimate loading for heavy-trucks will also be made and then the transit bus data can then be applicable to heavy trucks.

The final results will be a set of relationships that can be used to evaluate the emission reductions that can be achieved thru the use of different biodiesel blends under actual on-road operating conditions. Results are applicable and can be used by all agencies in the CenSARA region. Results can be used to evaluate different transportation management strategies such as use of biodiesel in fleets as well as the policy implications of encouraging specific levels of biodiesel use.

Study length: Task 4 will take approximately 6 months.

Estimation of time Emissions are present/Quantity & Emission Species:
Since we are dealing with mobile sources, emissions are present at all times. The emissions under study include PM, NO_x, CO and HC as well as the green house gas CO_2.

Cost: The requested amount for Task 4 is $89,281. An in-kind match will be provided from the CyRide in the amount of $45,350. They will provide the use of the buses and some project oversight. The estimated cost to rent transit buses for the duration of the study is (2 buses for 20 days including bus rental and overhead rate). The Department of Civil, Construction, and Environmental Engineering at ISU will provide a match of 0.6 months of salary for Shauna Hallmark. The amount with a fully loaded overhead is $11,141. Total cost for Task 4 including the match is $145,772.

Task 5: Develop a truck inventory and compare emissions reductions from use of different biodiesel blends for the Quad Cities Metropolitan area

Task 6: Summarize results and develop material so that other agencies can compare emission impacts of regular and different biodiesel blends in reducing truck emissions either on a localized or regional scale

The final task will be to prepare a final report which details the methodologies and results for each task. Additionally, outreach material will be prepared that are geared towards to various stakeholders in the CenSARA region who undertake evaluation of emission strategies. The results will be presented in a format so that agencies can better evaluate the emission reduction potential of strategies that include use of bio-diesel. The results will provide state of the art knowledge in understanding the emission impacts of using different biodiesels blends and the results will be geared so that agencies can evaluate different alternatives in meeting their responsibilities under Clean Air Act.

Results will be presented so that the material can be used to evaluate emission on either a project level or regional scale.

Cost: Estimated cost for Task 6 is $3,142. The Department of Civil, Construction, and Environmental Engineering (CCEE) at ISU will provide a match of 0.2 months of salary for Shauna Hallmark. The amount with a fully loaded overhead is $3,714. Total cost for Task 5 including the match is $6,856.

7. RELATIONSHIP TO OBJECTIVES OF NATIONAL CLEAN DIESEL CAMPAIGN

8. SUMMARY AND TIMELINE

9. BUDGET

10. REFERENCES

APPENDIX A: RESUMES

Exhibit B
Contract 08-7210-01

Evaluation of On-Road and Laboratory Engine Dynamometer Emission Tests to Compare the Emission Reduction Potential of Different Biodiesel Blends—**UPDATED March 29, 2007**

PROJECT LEAD: Jim McGraw, Environmental Program Supervisor, Program Development Section, Air Quality Bureau, Iowa DNR. Phone: (515) 242-5167. Email: Jim.McGraw@dnr.state.ia.us.

Proposing Organization: Iowa Department of Natural Resources (DNR) with Center for Transportation Research and Education (CTRE) at Iowa State University (ISU) as subcontractors.

CTRE Team: Shauna Hallmark (PI), phone: (515) 294-5249, email: shallmar@iastate.edu; Song-Charng (Co-PI**)**, Mechanical Engineering, Phone (515) 294-3244, email: kong@iastate.edu; Dennis Kroeger (co-PI). Center for Transportation Research and Education, Iowa State University. 2711 S. Loop Drive, Suite 4700, Ames, IA 50010-8664. Fax: (515) 249-0467.

SUBMITTED TO: Central States Air Resource Agencies Association. Mr. Jeffery Cole, email: jcole@censara.org

This document provides updates to task 1 as per the conversation between the project team and EPA. An updated cost for Task 1 is also provided ($24,068). The requested amount for Task 4 remains at $89,281. Several changes to Task 4 were requested but do not significantly change project scope or cost and will be finalized in a work plan before project work commences. Task 6 will need to be completed in order to summarize results but at a lower amount than originally requested. We estimate an amount of $2,750. This brings the total amount requested from CenSARA to complete updated Task 1, Task 4, and Task 6 from the original proposal to $116,099.

Revised Task 1: Evaluate and compare emissions for regular diesel and different biodiesel blends using laboratory engine dynamometer tests

Background

In-laboratory engine dynamometer tests will be performed to compare the emissions from regular diesel and different biodiesel blends for Task 1. The engine test facilities are described in Section 5.2. As noted the regular diesel fuel used in this study is ultra low sulfur diesel (ULSD) fuel. Previously published test data on biodiesel combustion were mainly based on diesel fuel with higher sulfur contents. Since the mandate of using ULSD has come into effect for on-highway vehicles, it is important to characterize the engine performance of using biodiesel blended with ULSD. In addition, new diesel emissions standards have resulted in the development of low-emission engines that are known to operate at different combustion regimes from the older models. It is also important to re-do the tests on new engines such as the new engine that is available in our laboratory that uses a start-of-the-art injection system.

Study Area: All of Task 1 will be conducted in the engine dynamometer lab on Iowa State Campus in Ames, Iowa.

Methodology: Extensive engine tests will be performed on a commercial turbocharged multi-cylinder engine manufactured by John Deere. Emissions will be evaluated using regular ULSD, 5% and 20% biodiesel blends. The test will measure engine power and exhaust emissions. Fuel economy and particulate and gaseous emissions, including NO_x, HC and CO, will be recorded.

The first replication will evaluate ULSD. For each fuel type, three different load conditions that are representative of regular engine operation will be tested. This includes peak torque (1400 rpm, 220 ft-lb), rated power (2100 rpm, 187 ft-lb) and light load (1200 rpm, 30 ft-lb). Steady-state tests will be performed for each load conditions based on the procedure described below.

A data acquisition system is already in place in the engine laboratory. The data system is capable of acquiring fueling rate, engine power and all the emissions data automatically. The data are averaged over the duration of each individual test. The data will be analyzed to assess each of the emission with respect to the fuel type. Data from Replication 1 will be evaluated to check data quality. If problems are noted in the data or equipment malfunctions occur, Replication 1 will be repeated before fuels are switched for Replication 2.

Note that to eliminate the effects of residual fuels, different fuel tanks will be used for different blends. In addition, transition between replications will be made by using ULSD to re-establish baseline conditions.

Replication 1
ULSD will be used. The emissions analyzer will be warmed up and calibrated at the beginning of each day. A gas divider will be used to blend the calibration gas for calibration. For each day of engine testing, the engine will be warmed up until steady state conditions are reached, approximately one hour as determined by steady coolant and oil temperature readings. Then, the engine will continue to run at the steady state condition for one hour for stabilization. After the stabilization, the engine will be tested on one load condition for two hours for power and emissions measurements. Engine data within the two-hour test time for a specific load will be analyzed and reported.

Since each load will result in different engine operating conditions, e.g., coolant temperatures, different load conditions will require different days of testing. At each day, the emissions analyzer and engine will be warmed up in the same way.

Replication 2
The test will use 5% biodiesel blends. The emissions analyzer and engine will be warmed up and stabilized at the beginning of each test day. The test protocol will be the same as Replication 1 except that the fuel is B5.

After Replication 2 has been finished, the engine will be run using regular ULSD for a period of time to stabilize the engine to reach previous steady state conditions of using ULSD. The transition time will be at least two hours or as necessary to re-establish the steady state conditions. This is also to eliminate the effects of residual biodiesel in the fuel system.

Replication 3
The test will use 20% biodiesel blends. The emissions analyzer and engine will be warmed up and stabilized at the beginning of each test day. The test protocol will be the same as Replication 1 except that the fuel is B20. After Replication 3 has been finished, the engine will be run using regular ULSD for at least two hours or as necessary to re-establish the steady state conditions. This is also to eliminate the effects of residual biodiesel in the fuel system.

Data from each replication will be evaluated in terms of emissions by load. Emissions are measured in terms of engine loads in units of g/kW-hr. As a result, the emission measurement is mass of emissions per unit fuel energy burned. More engine loading translates to more fuel

energy and higher emission. As a result relationships between loading and emissions will be derived for each fuel blend.

Calibrate PEMS equipment in laboratory engine testing
The PEMS equipment will be calibrated against the laboratory emissions analyzer. In-laboratory emissions measurements using the PEMS equipment will be conducted simultaneously with the laboratory emissions analyzer. Comparisons of emissions data obtained by two different analyzers will be reported.

Results: This task will result in a set of relationships between heavy-duty diesel engine load and emissions for different biodiesel blends. This information will be presented in a format so that the impact of using different biodiesel blends on heavy-duty vehicle emissions can be estimated. For instance, a trucking or transit agency can use to results to evaluate the emissions reduction likely to result from dedicated use of 5% or 20% biodiesel and determine the feasibility of using dedicated fleet refueling stations with biodiesel blends. Agencies concerned about PM, NOx, HC, ozone, or CO can also use this information to forecast emissions reductions from control strategies that encourage use of biodiesel. These results are applicable across all agencies within the CenSARA region.

Study length: Task 1 will take approximately 6 months.

Type of Emissions Measured and Estimation of Time Emissions are present: Since this is a laboratory test emissions are present at all times during the test. The emissions under study include particulate matter, NO_x, CO and HC.

Cost: This approximate cost for this task is $24,068.